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Examining the link between energy consumption, carbon dioxide emission, and economic growth in Latin America and the Caribbean

Usama Al-mulali*, Janice YM Lee[1], Abdul Hakim Mohammed[2], Low Sheau-Ting[3]

Centre for Real Estate Studies, Department of Real Estate, Faculty of Geoinformation & Real Estate, Universiti Teknologi Malaysia, Johor Bahru Johor 81310, Malaysia

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ABSTRACT

This study aims at exploring the bi-directional long run relationship between energy consumption, Carbon Dioxide emission, and economic growth in the Latin American and Caribbean countries. The Canonical Cointegrating Regression (CCR) is used to achieve the goal of this study taking the period of 1980–2008. The study arrived at different results. While 60% of the countries have a positive bi-directional long run relationship between energy consumption, Carbon Dioxide emission, and economic growth, the others have mixed results. The results of the study motivated the researcher to recommend that these countries should increase their energy efficiency, increase the share of green energy from their total energy use, and increase energy conservation in order to reduce unnecessary waste of energy.

Contents

1. Introduction

The increasing concern of the greenhouse gas emission has motivated many researchers to study the relationship between energy consumption, Carbon Dioxide emission, and economic growth in different countries and regions. However, this relationship has been rarely investigated in the Latin American and Caribbean countries despite the fact that their energy consumption and Carbon Dioxide emission increased more than double in the last three decades. Unlike the previous studies that mostly focused on the short run causal relationship between the variables, this study will investigate the bi-directional long run relationship between energy consumption, Carbon Dioxide emission, and economic growth. Most of the previous studies have arrived at the conclusion that despite the fact that energy is an important indicator to achieve economic growth and development, it increases the level of greenhouse gas emission due to the

* Corresponding author. Tel.: +60174587786; fax: +60 075566163.
E-mail addresses: usama81za@gmail.com,
usama_81z@yahoo.com (U. Al-mulali), janicelee@utm.my (J.Y. Lee),
abdhakim@utm.my (A. Hakim Mohammed),
lowsheauting@hotmail.com (L. Sheau-Ting).
[1] Tel.: +60197772188.
[2] Tel.: +60197502150.
[3] Tel.: +60167186819.

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world dependence on fossil fuels which played more than 81% of the world total energy consumption in 2009.

Section 2 below reviews the studies that have investigated the relationship between energy consumption and economic growth, and Section 3 reviews the studies that have explored the link between energy consumption, Carbon Dioxide emission, and economic growth.

2. Studies on the relationship between energy consumption and growth

Although the relationship between energy consumption and growth has been carefully studied by researchers, this type of relationship is investigated rather limitedly in the Latin American and Caribbean countries. Fallahi [1] found a bi-directional causal relationship between energy consumption and economic growth in the United States. Li and Leung [2] found a long run and a one way causal relationship from coal consumption to economic growth in China. Similar results were found in China by Wang et al. [3]. Shahiduzzaman and Alam [4] found that in Australia energy consumption and economic growth are cointegrated. Moreover, the researcher also indicated that there is a bi-directional causal relationship between the variables. The same results were found by Fuinhas and Marques [5] in Turkey, Belke et al. [6] in the OECD countries, Zhang [7] in Russia, Ouedraogoa [8] in a number of African countries, Coers and Sanders [9] in the OECD countries, and Baranzini et al. [10] in Switzerland. Zhixin and Xin [11] found that energy consumption and economic growth are highly correlated and that the economic growth is heavily dependent on energy consumption in Shandong province. Wei and Gang [12] found a one way causal relationship from energy consumption to economic growth in China. In the G-7 countries, Salamaliki and Venetis [13] found a one way causal relationship from economic growth to energy consumption. Furthermore, You [14] found that the renewable energy consumption increases economic development by increasing China's genuine savings while fossil fuels energy consumption increases economic growth only. In the former Soviet Republics, Bildirici and Kayıkçı [15] found a long run and a causal relationship between electricity consumption and economic growth. Kahsai et al. [16] found that in the Sub Saharan African countries the long run and causal relationship between energy consumption and economic growth are prone to get stronger in high income countries and get weaker in low income countries. In a number of Middle Eastern and North African countries (MENA), it was found that the long run relationship does not exist in Iran, Morocco, and Syria, while it does exist in Egypt, Israel, Oman, and Saudi Arabia. The overall results indicated that there is no evidence of a relationship between electricity consumption and economic growth in most of the MENA countries, [17]. Similar results were found in Turkey by Yalta [18]. In addition, Narayan and Popp [19] found a negative causal relationship between energy consumption and economic growth in the G6 countries. In the G-7 countries, a bi-directional causal relationship was found between gas consumption and economic growth with the exception of Italy where a one way causal relationship from natural gas consumption to economic growth was found [20]. Moreover, Das et al. [21] indicated that in Bangladesh there is a one way causal relationship from economic growth to natural gas energy consumption.

3. Studies on the relationship between energy consumption, CO_2 emission, and growth

The relationship between energy consumption, Carbon Dioxide emission and economic growth has been investigated by many researchers in different countries and regions. In Brazil, Russia, India, and China, for instance, Pao and Tsai [22] found that both energy consumption and economic growth have a long run significant relationship with Carbon Dioxide emission, a bi-directional causal relationship between energy consumption and Carbon Dioxide emission, and between energy consumption and economic growth, and a unidirectional causal relationship between Carbon Dioxide emission and economic growth. Moreover, Wang et al. [23] found that energy consumption, economic growth, and Carbon Dioxide emission are cointegrated and have a bi-directional causal relationship in China. Bloch et al. [24] found the same relationship between coal consumption, economic growth, and Carbon Dioxide emission in China. Consequently, it was indicated that it is difficult for China to apply a greenhouse gas polices via reducing coal consumption and replacing it with greener energy sources. In a number of Asian Pacific countries, Niu et al. [25] found that energy consumption, economic growth, and Carbon Dioxide emission are cointegrated. Moreover, the researchers also indicated that there is causal relationship between energy consumption and Carbon Dioxide emission. However, the significance of such relationship varied between the developed and the developing countries because the level of energy efficiency was found to be higher in the developed countries than in developing countries. In addition, Alam et al. [26] found a one way causal relationship from energy consumption to economic growth and from Carbon Dioxide emission to economic growth. A bi-directional causal relationship was also found between energy consumption and Carbon Dioxide emission in Bangladesh. In China, Jalil and Mahmud [27] indicated the existence of the Kuznets curve and a one way causal relationship between economic growth and Carbon Dioxide emission. In addition, the study found that Carbon Dioxide emission was determined by income and energy consumption. The same results were found by Acaravci and Ozturk [28,29] in the European countries and Turkey. In Brazil, Pao and Tsai [30] found a long run and a bi-directional causal relationship between energy consumption, Carbon Dioxide emission and economic growth. Similar results were found by Pao et al. [31] in Russia, Al-mulali [32] in the Middle East and North African countries, Al-mulali and Che Sab [33] in the Sub Saharan African Countries, and Govindaraju and Tang [34] in China. Moreover, in South Korea, Park and Hong [35] found a strong correlation between energy consumption, Carbon Dioxide emission and economic growth. The same results were found in Romania by Shahbaz et al. [36]. In the United States, a long run and a causal negative relationship between nuclear energy consumption and Carbon Dioxide emission was found. The study also indicated that there is a long run positive and no causal relationship between renewable energy consumption and Carbon Dioxide emission [37]. In newly industrialized countries, a long run relationship between energy consumption, Carbon Dioxide emission, and economic growth was found. It was also indicated that there is a one way causal relationship from economic growth to Carbon Dioxide emission and from economic growth to energy consumption [38]. Sari and Soytas [39] found a long run relationship between income, energy consumption and Carbon Dioxide emission in Saudi Arabia, but not in Indonesia, Algeria, Nigeria, and Venezuela. Moreover, no causal relationship between the variables was found, thus, energy conservation can help reduce the amount of Carbon Dioxide emission without affecting the countries' economic growth. In addition, Soytas et al. [40] found that in the United States income has no causal relationship with Carbon Dioxide emission, but energy does, hence, income might not be a solution for the environmental problems.

4. Methodology

The main objective of this study is to examine the bi-directional long run relationship between energy consumption,

Carbon Dioxide emission, and economic growth in Latin American and the Caribbean countries taking the period of 1980–2008. These countries are Antigua and Barbuda, Argentina, The Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, and Venezuela.

To achieve the goal of this study, the following three time series models are built:

$$\mathrm{LGDP_t} = \alpha + \beta_1\ \mathrm{LECON_t} + \beta_2\ \mathrm{LCEM_t} \tag{1}$$

$$\mathrm{LECON_t} = \alpha + \beta_3\ \mathrm{LGDP_t} + \beta_4\ \mathrm{LCEM_t} \tag{2}$$

$$\mathrm{LCEM_t} = \alpha + \beta_5\ \mathrm{LECON_t} + \beta_6\ \mathrm{LGDP_t} \tag{3}$$

LGDP is the log of the gross domestic product measured in billions of constant national currency, LECON is the log of the total primary energy consumption measured in Quadrillion Btu, LCEM is the log of the total carbon dioxide emissions from the consumption of energy measured in million of metric tons. α is the intercept, and $\beta_{1,}$ $\beta_{2,}$ $\beta_{3,}$ β_4, β_5, and $\beta_{6,}$ are the slope coefficients of the models.

4.1. Data source

The data for the gross domestic product was taken from the World Economic Outlook (WEO). The data for the total primary energy consumption and the total carbon dioxide emissions from the consumption of energy was retrieved from Energy Information Administration (EIA).

4.2. Unit root test

Testing the stationarity of the variables has become one of the most popular tests. It is widely used by researchers, especially economists and econometrician. The common unit root test and the Augmented Dickey–Fuller (ADF) are used in this study. The ADF test is commonly used when the error term is highly correlated. Consider its following regression:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \textstyle\sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \varepsilon_t \tag{4}$$

ε_t is the pure white noise error term, $\Delta Y_{t-i}=(Y_{t-1}-Y_{t-2})$. The number of lagged difference terms which it includes is determined empirically. The reason behind including enough terms is to make the white noise error term serially uncorrelated

The ADF unit root test has three cases, namely, without constant and trend, with constant but no trend, and with constant and trend. The following represents the null and the alternative hypotheses for each of the three cases:

H_0: $\gamma=0$ (y_t is non-stationary) and H_1: $\gamma<0$ (y_t is stationary)

The τ statistic used in the test is a negative number. The more negative it is, the stronger the rejection of the null hypothesis is. This means that there is a unit root at some chosen level of significance. Since γ is generally expected to be negative, the estimated τ statistic will have a negative sign. Therefore, a larger negative τ value is an indication of stationarity.

4.3. Canonical cointegrating regression (CCR)

Proposed by Park [41], this single cointegration equation employs stationary transformation of the (y_i ,X_t') data to obtain the least square estimates to eliminate the long run dependence between the cointegration equation and the stochastic regressors innovations. The CCR eliminates the endogeneity caused by the long run correlation of the cointegrating equation errors and the stochastic regressors innovations, and simultaneously correct the asymptotic bias resulting from the contemporaneous correlation between the regression and stochastic regressor errors. The CCR whose estimates follow a blend normal distribution which is free of non-scalar nuisance parameters is unbiased. It permits asymptotic Chi-square testing, and can work with variables which are stationary in different levels. The first step of this test is to obtain innovations $\hat{\mu}_t=(\hat{\mu}_{1t},\ \hat{\mu}_{2t'})'$ and corresponding constant estimates of the long-run covariance matrix $\hat{\Omega}$ and $\hat{\Lambda}$. The CCR also requires a constant estimator of the modern covariance matrix $\hat{\Sigma}$. The columns $\hat{\Lambda}$ corresponding is basically extracted to the one-sided long run covariance matrix of $\hat{\mu}_t$ and $\hat{\mu}_{2t}$.

$$\hat{\Lambda}_2 = \begin{bmatrix} \hat{\lambda}_{12} \\ \hat{\lambda}_{22} \end{bmatrix} \tag{5}$$

After that, Park transformed (y_i ,X_t') using

$$X_t^* = X_t - (\hat{\Sigma}^{-1}\hat{\Lambda}_2)'\hat{\mu}_t$$

$$y_t^* = y_t - \left[\hat{\Sigma}^{-1}\hat{\Lambda}_2\tilde{\beta} + \begin{bmatrix} 0 \\ \hat{\Omega}_{22}^{-1}\hat{\omega}_{21} \end{bmatrix}\right]'\hat{\mu}_t \tag{6}$$

$\tilde{\beta}$ is the estimates of the cointegration equation coefficient. Moreover, the CCR estimators are similar to the definition of the least square but applied to the transformed data

$$\begin{bmatrix} \hat{\beta} \\ \hat{\gamma}_1 \end{bmatrix} = \left[\sum_{t=1}^{T} Z_t^* Z_t^{*\prime}\right]^{-1} \sum_{t=1}^{T} Z_t^* y_t^* \tag{7}$$

where $Z_t^*=(Z_t^{*\prime},\ D_{it}')'$.

5. Empirical results and discussion

Table 1 (see Appendix A) reviews the ADF unit root test results. It shows that more than 95% of the variables are stationary at the first difference while the rest are stationary at levels and the first difference which in turn rejecting the null hypothesis.

5.1. Canonical cointegrating regression (CCR) test results

Since the variables are stationary, the CCR test is performed to examine the long run relationship between energy consumption, Carbon Dioxide emission, and economic growth in the investigated countries. Table 2 (see Appendix A) below indicates that the results for the CCR test are mixed across the countries. While a positive bi-directional long run relationship between energy consumption and economic growth was found in Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Jamaica, Nicaragua, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, and Uruguay, a negative bi-directional long run relationship between energy consumption and economic growth was found in Antigua and Barbuda and The Bahamas. A one way positive long run relationship was found between energy consumption and economic growth in Bolivia, Panama, Paraguay, Peru, and Venezuela. Moreover, a positive one way long run relationship was found between economic growth and energy consumption in Belize, Brazil, Dominica, Honduras, and Mexico, but there was no such relationship in Argentina and Barbados.

Regarding the relationship between economic growth and Carbon Dioxide emission, a long run bi-directional positive relationship was found between the two variables in Antigua, Barbuda, The Bahamas, Dominica, Ecuador, Guyana, Honduras, Jamaica, Mexico, Nicaragua, Paraguay, St. Kitts and Nevis, St. Lucia, Suriname, and Trinidad and Tobago. On the other hand, a long run

Table 1
ADF unit root test results.

Country	Variable	The augmented Dickey–Fuller (ADF)			
		Level		First difference	
		Intercept	Intercept and trend	Intercept	Intercept and trend
Antigua and Barbuda	**LGDP**	0.322278	2.189810	3.880095[b]	3.796092[b]
	LECON	0.111776	1.608793	3.699871[b]	4.339330[a]
	LCEM	0.138851	2.073535	4.207540[a]	3.167203[b]
Argentina	**LGDP**	0.092477	2.393135	3.581803[b]	3.697089[b]
	LECON	0.079258	2.931425	6.799532[a]	6.690775[a]
	LCEM	0.127788	2.244089	5.614549[a]	5.517085[a]
The Bahamas	**LGDP**	1.573522	2.387216	3.225304[a]	3.182388[a]
	LECON	0.955597	0.282308	3.565708[a]	4.141356[a]
	LCEM	0.759888	0.213749	3.758730[a]	4.248540[a]
Barbados	**LGDP**	0.809279	3.058530	3.011892[b]	2.940888
	LECON	2.728339	0.777627	8.226283[a]	4.092362[b]
	LCEM	2.621689	3.961593[b]	8.309327[a]	8.250010[a]
Belize	**LGDP**	0.550629	3.365424[c]	3.369459[b]	3.358112[b]
	LECON	0.067368	2.826812	4.897397[a]	4.928719[a]
	LCEM	0.221548	2.872913	5.329357[a]	5.289330[a]
Bolivia	**LGDP**	2.862457	2.650145	1.858795	6.963684[a]
	LECON	0.380884	2.656743	4.628837[a]	3.582919[c]
	LCEM	0.200631	2.792914	4.365490[a]	4.408954[a]
Brazil	**LGDP**	1.176416	4.215538[b]	4.165824[a]	4.122954[b]
	LECON	0.464396	3.521170	7.031486[a]	6.893555[a]
	LCEM	0.304689	2.726683	4.587682[a]	4.467805[a]
Chile	**LGDP**	0.440071	2.389337	3.673206[b]	3.721963[b]
	LECON	0.161673	2.377898	4.690134[a]	4.596779[a]
	LCEM	0.201475	3.181551	3.627116[b]	3.505668[b]
Colombia	**LGDP**	0.044994	2.324032	3.032757[b]	2.985772
	LECON	1.384625	2.684218	7.026165[a]	7.108119[a]
	LCEM	1.275553	2.689784	5.272516[a]	5.173859[a]
Costa Rica	**LGDP**	0.977248	5.730137[a]	6.934336[a]	6.728788[a]
	LECON	0.149928	2.386394	5.513823[a]	5.435231[a]
	LCEM	0.181193	2.109077	4.431278[a]	4.295496[a]
Dominica	**LGDP**	1.773592	1.942629	5.054313[a]	5.105688[a]
	LECON	3.078166[c]	2.924052	6.222422[a]	4.844589[a]
	LCEM	1.143191	1.608175	5.809245[a]	6.180471[a]
Dominican Republic	**LGDP**	1.527651	2.165509	3.854189[b]	4.226770[a]
	LECON	0.596982	3.186099	7.565071[a]	7.431063[a]
	LCEM	0.779592	4.882618[a]	7.454779[a]	7.445955[a]
Ecuador	**LGDP**	1.059720	2.336480	6.044635[a]	6.565269[a]
	LECON	0.311356	1.684571	9.670268[a]	4.339330[a]
	LCEM	0.182630	2.792246	7.403319[a]	7.368650[a]
El Salvador	**LGDP**	0.526814	1.302251	3.370489[b]	2.876260
	LECON	0.011553	2.601210	5.863145[a]	5.704123[a]
	LCEM	0.529641	1.659433	5.323672[a]	5.263821[a]
Grenada	**LGDP**	0.376146	0.247481	5.921182[a]	5.811272[a]
	LECON	0.972804	3.275371	7.348968[a]	7.249625[a]
	LCEM	1.167561	3.042508	6.905063[a]	6.808017[a]
Guatemala	**LGDP**	3.198804	1.609798	6.420263[a]	6.443083[a]
	LECON	0.323224	4.327030[b]	7.242406[a]	7.003149[a]
	LCEM	0.360367	3.069832	5.668204[a]	5.608157[a]
Guyana	**LGDP**	0.707698	2.492392	2.750099[c]	3.075849
	LECON	1.372330	1.725997	4.354877[a]	4.491594[a]
	LCEM	1.370376	1.805050	4.596143[a]	4.680113[a]
Haiti	**LGDP**	1.844862	1.849619	4.686353[a]	4.797609[a]
	LECON	1.196868	2.487364	5.551306[a]	5.403211[a]
	LCEM	1.202830	2.687028	5.824065[a]	5.666127[a]
Honduras	**LGDP**	2.076971	1.573617	4.432501[a]	5.223569[a]
	LECON	0.062306	3.100296	5.766028[a]	4.983317[a]
	LCEM	0.495346	3.960948[c]	4.059741[a]	3.679461[c]
Jamaica	**LGDP**	2.337161	2.154037	2.487787	3.724070[b]
	LECON	0.227225	3.225334	3.934343[a]	3.706331[b]
	LCEM	0.164008	3.193594	3.821451[b]	3.605345[b]
Mexico	**LGDP**	0.223202	2.247492	5.360307[a]	5.601306[a]
	LECON	0.121716	1.609571	7.120696[a]	6.961290[a]
	LCEM	0.622531	0.703311	6.940217[a]	6.889080[a]
Nicaragua	**LGDP**	0.316319	0.605392	3.128176[c]	4.025052[a]
	LECON	0.547430	3.485116	7.509215[a]	5.757000[a]
	LCEM	0.133667	2.150539	4.923026[a]	4.852053[a]
Panama	**LGDP**	1.742151	1.933609	3.028507[b]	4.283586[a]
	LECON	0.776104	3.320184	5.908222[a]	6.261970[a]
	LCEM	1.813655	2.403400	6.444762[a]	6.406859[a]
Paraguay	**LGDP**	0.702359	1.971110	4.087677[a]	4.115649[a]
	LECON	2.302279	0.639677	5.606940[a]	6.229776[a]

Table 1 (*continued*)

Country	Variable	The augmented Dickey–Fuller (ADF)			
		Level		First difference	
		Intercept	Intercept and trend	Intercept	Intercept and trend
	LCEM	2.361245	0.451739	6.929978[a]	4.487584[a]
Peru	LGDP	0.785789	0.711518	3.180356[b]	3.350516[b]
	LECON	0.598632	2.076650	3.645792[b]	4.007302[b]
	LCEM	0.339236	1.032958	3.801545[b]	4.174809[a]
St. Kitts and Nevis	LGDP	0.816249	1.868065	4.523047[a]	4.548153[a]
	LECON	1.537371	1.846452	4.533009[a]	5.141634[a]
	LCEM	1.462644	2.020635	4.449629[a]	4.956252[a]
St. Lucia	LGDP	2.426283	1.079505	4.760998[a]	4.623150[a]
	LECON	0.231030	3.570506[c]	7.082083[a]	6.889634[a]
	LCEM	0.217184	1.609798	7.077322[a]	6.881789[a]
St. Vincent and the Grenadines	LGDP	1.548791	1.777341	5.820451[a]	6.011092[a]
	LECON	0.638749	2.691273	6.247840[a]	6.174445[a]
	LCEM	0.528164	2.093153	5.733214[a]	3.369618[a]
Suriname	LGDP	0.479623	1.964800	6.963107[a]	6.882754[a]
	LECON	1.911447	3.357315	4.830419[a]	4.917863[a]
	LCEM	1.128818	0.151164	3.323327[b]	3.088516
Trinidad and Tobago	LGDP	1.573522	2.387216	3.225304[b]	3.182388
	LECON	0.955597	3.828374[b]	3.565708	4.141356[a]
	LCEM	0.759888	1.071840	3.758730[b]	4.248540[a]
Uruguay	LGDP	0.079623	3.120806[c]	2.936001	3.073728[c]
	LECON	1.091459	0.509340	8.465241[a]	8.279477[a]
	LCEM	0.662038	1.683674	3.766253[b]	3.928312[b]
Venezuela	LGDP	0.496313	1.661753	4.274274[b]	4.404785[a]
	LECON	0.522899	1.516860	7.608443[a]	5.602510[a]
	LCEM	0.471262	0.313172	5.550448[a]	5.547526[a]

[a] Is Significant at 1%.
[b] Is Significant at 5%.
[c] Is significant at 10%.

bi-directional negative relationship between economic growth and Carbon Dioxide emission was found in Haiti and Uruguay. Moreover, a one way long run positive relationship was found between Carbon Dioxide emission and economic growth in Bolivia while a one way long run positive relationship between economic growth and Carbon Dioxide emission was found in Colombia and Venezuela. Finally, there was no long run relationship between economic growth and Carbon Dioxide emission in Argentina, Barbados, Belize, Brazil, Chile, Costa Rica, Dominican Republic, El Salvador, Grenada, Guatemala, Panama, Peru, and St. Vincent and the Grenadines.

Concerning the relationship between energy consumption and Carbon Dioxide emission, a positive bi-directional long run relationship between the energy consumption and Carbon Dioxide emission was found in Antigua and Barbuda, The Bahamas, Chile, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad, Tobago, and Uruguay. In addition, a one way long run positive relationship was found between Carbon Dioxide emission and energy consumption in Argentina, Barbados, Bolivia, Panama, and Peru, while a one way long run positive relationship was found between energy consumption and Carbon Dioxide emission in Belize, Brazil, Colombia, Costa Rica, Dominica, Honduras, Mexico, Nicaragua, Paraguay, and Venezuela.

6. Conclusion

This study explored the bi-directional long run relationship between energy consumption, Carbon Dioxide emission, and economic growth in the Latin America and Caribbean countries. To achieve the goal of the study, the Canonical Cointegrating Regression (CCR) Test was used taking the period of 1980–2008. The CCR test showed mixed results. Fifty-six percent of the countries have a long run bi-directional positive relationship between energy consumption and economic growth, 6% of the countries have a long run bi-directional negative relationship between energy consumption and economic growth, 16% of the countries were found to have a positive one way long run relationship between energy consumption and economic growth, 16% of the countries have a long run positive relationship between economic growth and energy, and 6% of the countries have no relationship between energy consumption and economic growth.

The relationship between economic growth and Carbon Dioxide emission was also examined and the results showed that there was a bi-directional long run positive relationship between the variables in 46% of the countries. On the other hand, a bi-directional negative long run relationship was found between economic growth and Carbon Dioxide emission in 6% of the countries. In addition, a one way long run positive relationship between economic growth and Carbon Dioxide emission was found in 6% of the countries while in Bolivia there was only a one way positive long run relationship between Carbon Dioxide emission and economic growth. No relationship was found between the variables in 41% of the countries.

A bi-directional positive relationship between energy consumption and Carbon Dioxide emission was found in 53% of the countries. Moreover, a positive one way long run relationship between Carbon Dioxide emission and energy consumption was found in 16% of the countries while a positive one way long run relationship between energy consumption and Carbon Dioxide emission was found in 31% of the countries.

The results of the study motivated the researcher to recommend that these countries should increase their energy efficiency, increase the share of green energy from their total energy use, and increase energy conservation in order to reduce unnecessary waste of energy.

Table 2
Canonical cointegrating regression (CCR) Test Results.

Country	The direction of the relationship					
	LECON→LGDP	LCEM →LGDP	LGDP→LECON	LCEM→LECON	LECON→LCEM	LGDP→LCEM
Antigua and Barbuda	−5.015716[c] (−1.843913)	6.289007[b] (2.431296)	−1.003087[a] (−3.36705)	0.034321[c] (1.786949)	0.980921[a] (3.62475)	0.043414[b] (2.376851)
Argentina	0.295782 (0.575368)	0.809710 (1.258286)	0.114885 (0.742390)	1.130797[a] (6.186299)	0.295782 (0.575368)	0.809710 (1.258286)
The Bahamas	−3.330661[a] (−3.719181)	3.913859[a] (4.383194)	−0.142105[a] (5.983566)	1.075007[a] (3.05153)	0.911678[a] (3.95691)	0.143623[a] (4.461239)
Barbados	−0.962582 (−0.723886)	1.449095 (1.279860)	−0.080715 (−1.081737)	0.883241[a] (16.21745)	−0.962582 (−0.723886)	1.449095 (1.279860)
Belize	0.293855 (0.171098)	0.506442 (0.280080)	1.041681[a] (4.87232)	0.008299 (0.183296)	0.944402[a] (6.12915)	0.011663 (0.283104)
Bolivia	0.401199[a] (4.548419)	0.207666[b] (2.423578)	0.211713 (1.030622)	1.312615[a] (3.778454)	0.500957 (1.303018)	0.778356 (1.220982)
Brazil	0.349927 (0.835587)	0.344936 (0.742016)	0.969412[a] (7.724984)	0.175697 (1.010236)	0.807487[a] (4.960302)	0.144111 (0.577121)
Chile	0.946554[b] (2.700182)[a]	0.070701 (0.207224)	0.686846[a] (5.266266)	0.292939[b] (2.207936)	0.912438[a] (4.399060)	0.106079 (0.518155)
Colombia	1.796683[a] (5.128334)	−0.453266 (−0.993925)	0.918678[a] (5.113875)	−0.096253 (−0.794017)	0.672960[a] (5.643055)	0.320552[a] (4.946120)
Costa Rica	0.804476[a] (5.776507)	0.051604[a] (0.350421)	0.401105[b] (2.656632)	0.713246[a] (4.171572)	0.682418[c] (1.961067)	0.332092[a] (0.803385)
Dominica	−0.149969 (−0.449255)	0.648228[b] (2.045429)	1.009440[a] (8.484005)	−0.118959 (−0.506526)	0.840719[a] (8.334076)	0.394268[b] (2.081502)
Dominican Republic	1.551451[b] (2.664156)	−0.597239 (−1.090638)	0.694247[a] (7.475398)	0.296569[a] (2.731713)	1.254803[a] (8.312797)	−0.226789 (−1.368168)
Ecuador	0.481476[b] (2.160454)	0.434049[c] (1.709550)	0.554250[c] (1.749710)	0.601157[c] (1.822539)	0.428576[c] (1.746290)	0.517971[c] (1.784643)
El Salvador	0.537580[c] (3.410622)	0.125242 (0.986572)	0.279469[c] (1.723404)	0.956888[a] (3.284828)	0.973293[b] (2.570490)	2.570490 (0.505203)
Grenada	1.861216[c] (1.741828)	−1.230529 (−1.143308)	0.952669[a] (6.83616)	0.084030[c] (1.529756)	1.025203[a] (6.14443)	−0.051425 (−0.842168)
Guatemala	0.495435[a] (4.228588)	0.063976 (0.586758)	0.351790[b] (2.179395)	1.070966[a] (3.339973)	0.826717 (1.784967)	0.496576[a] (0.592705)
Guyana	2.090609[a] (3.942420)	2.659192[a] (4.946735)	1.084408[a] (3.82078)	0.142192[a] (2.739169)	0.901464[a] (3.49443)	0.155899[a] (3.506216)
Haiti	0.916994[b] (2.261298)	−0.690184[c] (−2.058275)	0.800486[a] (5.67782)	0.311714[b] (2.468468)	1.245261[a] (5.89281)	−0.378828[a] (−2.348584)
Honduras	0.177089 (1.134444)	0.358784[b] (2.771486)	0.540393[b] (2.594779)	0.563593 (1.303117)	0.691433[b] (2.676353)	0.875379[c] (1.976989)
Jamaica	1.610700[a] (4.088692)	1.850374[a] (5.096597)	1.019299[a] (7.742644)	0.265469[a] (4.256993)	0.962847[a] (7.065433)	0.294689[a] (5.422551)
Mexico	0.387638 (1.373399)	0.879594[b] (2.721419)	0.855136[a] (3.491722)	0.200573 (1.070948)	0.369664[b] (2.416158)	0.441815[a] (3.289154)
Nicaragua	0.744987[c] (1.685246)	1.017308[a] (3.027761)	0.839625[a] (12.57207)	−0.096815 (−0.756311)	1.100231[a] (13.15156)	0.205840[c] (1.663800)
Panama	3.190761[a] (8.548226)	0.084316 (0.951522)	0.002554 (0.110319)	0.278661[a] (8.768296)	−0.540917 (−0.227580)	0.851196 (1.151767)
Paraguay	−0.015321 (−0.314048)	0.559897[a] (4.430769)	2.620046[b] (2.524529)	−0.671809 (−0.334618)	0.149791[b] (2.758828)	1.229402[a] (4.469581)
Peru	1.218078[a] (10.32059)	0.141777 (0.983217)	0.073824 (0.603992)	0.713251[a] (9.125176)	0.312701 (0.457490)	0.341610 (0.641372)
St. Kitts and Nevis	5.955116[a] (3.968226)	6.545153 (4.571030)	1.053838[a] (4.887564)	0.111302[a] (4.144693)	0.944347[a] (4.197124)	0.109926[a] (4.725086)
St. Lucia	6.011895[c] (1.796170)	6.511494[c] (1.986207)	1.005259[a] (7.702857)	0.040647[b] (2.339998)	0.992989[a] (8.600151)	0.043344[b] (2.610241)
St. Vincent and the Grenadines	0.890145[b] (2.408036)	−0.223797 (−0.722894)	0.685639[a] (7.540297)	0.288279[c] (1.703796)	1.267370[a] (7.803151)	−0.120757 (−0.475911)
Suriname	0.577667[b] (2.984812)	0.987037[a] (6.114946)	1.017640[a] (5.389006)	0.531395[c] (1.915198)	0.713843[a] (6.429991)	0.625356[a] (4.515329)
Trinidad and Tobago	3.330661[a] (3.719181)	3.913859[a] (4.383194)	1.075007[a] (3.051513)	0.142105[a] (3.709110)	0.911678[a] (3.952691)	0.143623[a] (4.461239)
Uruguay	1.581312[a] (5.017699)	−1.171819[a] (−3.093993)	0.895394[a] (13.74526)	0.372097[a] (4.068083)	1.028452[a] (14.15085)	−0.322397[a] (−2.798648)
Venezuela	−0.182381 (−0.245990)	1.244528 (1.241201)	1.392792[a] (10.53574)	−0.071971 (−0.578549)	0.624206[a] (9.326908)	0.160967[c] (1.898292)

→ Shows the direction of the relationship,
[a] Is significant at 1%.
[b] Is significant at 5%, the numbers in brackets are the *t*-statistics.

Appendix A. ADF unit root test and the canonical cointegrating regression (CCR) test results

See Appendix Tables 1 and 2.

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